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DIGESTIBLE NUTRIENTS AND METABOLIZABLE ENERGY IN RUSSIAN-THISTLE HAYS AND SILAGES[1]

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INTRODUCTION

For many years the Russian-thistle (*Salsola kali* L.) has been used as a feed for carrying livestock through the winter in the Great Plains area when little or no other forage was available. The dry years of 1934 and 1936 focused attention on this plant and emphasized the need of further information regarding its digestibility and usefulness as a feed. Since no determinations of digestibility were then available, this series of studies was undertaken. Later it was learned that digestion trials with cattle had been made by Cave, Riddell, and Hughes (*5*).[3]

THE RUSSIAN-THISTLE PLANT

DESCRIPTION

The compact, rounded form of the Russian-thistle plant is well known, but there is sometimes confusion in statements about the leaves becoming "spiny." The early leaves are as much as 2 or 3 inches long and are round in cross section. By the first of July, plants in the open may have reached a height of 1 to 1½ feet and are a mass of fleshy leaves, mostly with soft stems. About the middle of July the flowers begin to appear, and by the end of the month the plants are in full bloom. The plants continue to grow, the stems elongating and producing new branches and flowers until frost.

The leaves on the upper branches are not so long as those on the lower branches, and become shorter and shorter toward the ends of the branches. Flowers are borne singly at the nodes, each one just above the base of a leaf. Each flower is accompanied by two bracts, short, somewhat triangular, spine-tipped leaves about one-fourth of an inch long. On the upper branches the leaves themselves are reduced to the size of these bracts. On the lower stems the nodes may be as much as an inch apart, but toward the top of the plant they grow

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[3] Reference is made by number (italic) to Literature Cited, p. 92.

closer and closer together, so that the last few inches of each branch is crowded with "seeds," each one protected by the stem on one side and by the three spines on the other. The true leaves never have more than a very small spine, and a large proportion of them dry up or are eaten by insects.

The characteristic appearance of the upper branches with thick-set spines and winged fruits is not apparent until late August. In the lower, shaded part of the plant, the branches remain more leafy and succulent, so that large, old plants are by no means all hard and spiny.

The foregoing description is of plants growing in the open from seeds that germinate early in the spring. Those developing from seeds that germinate later in the season and from plants more or less shaded by other plants would be retarded in their development or would be variously modified. The chief difference probably would be in the size of the plant.

The Russian-thistle is especially well adapted to the dry plains region because of its ability to grow under dry conditions and to distribute its seeds when the mature plants are broken off and blown by the wind over the open country. Briggs and Shantz (*3*) found at Akron, Colo., that 336 pounds of water was used by the Russian-thistle in producing 1 pound of dry material. This is less than the quantity used by most other species, either weeds or crop plants, and much less than that used by wheat or flax. Dillman (*8*) obtained a still lower figure of 224 pounds at Mandan, N. Dak.

It is a matter of common observation that the Russian-thistle thrives during a dry season when most species make very poor growth. In 1934, when crop failure from drought was general in North Dakota, fields were covered with Russian-thistles, and they were common in the Red River Valley in the eastern part of the State where they are usually restricted to dry banks. In 1941, when moisture was more abundant, Russian thistles were remarkably inconspicuous. For a fuller account of this plant, see Stevens (*14*).

CHEMICAL COMPOSITION

As a part of this investigation, samples of Russian-thistle were collected from different parts of the State and at different stages of growth. Two series were secured from different soil types in the same general region at successive dates in 1936. The analyses of these samples are presented in table 1.

To facilitate comparison the data are calculated to a uniform water content of 15 percent. Wide variations in composition are noted. The ash varies from 12.07 percent to 24.36 percent and the protein (N×6.25) from 7.93 percent to 20.84 percent. The crude fiber varies from 11.16 percent in young succulent plants to 26.21 percent in a sample collected at Fargo, September 3, 1936. The nitrogen-free extract varies from 26.95 to 39.31 percent, and the ether extract varies from 1.18 to 2.00 percent.

It is interesting to note, particularly in the Fargo and Leonard samples, that the ash is highest in the young, tender plants and lowest in the more mature plants. This is also noticeable to some extent in the analyses of other samples. Similarly, protein tends to be higher in the young plants and lower in the older ones. However, other factors such as season, rainfall, and soil, undoubtedly have an impor-

TABLE 1.—*Chemical composition of Russian-thistles collected in North Dakota in 1934, 1935, and 1936*

Source of sample	Date collected	Description of sample or site from which collected	Water	Ash	Crude protein	Crude fiber	N-free extract	Ether extract	Phosphorus
			Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Mapleton	July 23, 1934	2 feet high	15.00	15.74	8.80	23.54	35.65	1.27	0.136
Bedford	do	18 inches high	15.00	13.33	9.78	24.57	36.14	1.18	.107
Page	do	8–10 inches high	15.00	16.04	15.35	14.98	37.19	1.44	.149
Barrie	Aug. 3, 1934	12–18 inches high	15.00	12.07	7.93	24.25	39.31	1.24	.218
Mott	July 11, 1935	Succulent	15.00	24.36	18.11	11.16	29.38	1.99	.....
Do	do	6 inches; crowded	15.00	18.90	17.48	15.38	32.06	1.18	.....
New England	Aug. 5, 1935	Field; rank	15.00	16.30	11.17	19.33	36.58	1.62	.....
Do	do	Field; small	15.00	20.37	16.12	14.98	32.25	1.28	.....
Fargo	Sept. 13, 1935	Compost heap	15.00	15.61	14.12	22.98	30.78	1.51	.....
Do	do	Railroad	15.00	12.41	13.85	24.95	32.20	1.59	.....
Do [1]	June 16, 1936	6–8 inches high	15.00	24.30	17.46	11.53	30.07	1.64	.....
Do.[1]	July 1, 1936	10–12 inches, first flowers	15.00	22.09	20.15	12.74	28.02	2.00	.....
Do.[1]	July 16, 1936	12–18 inches high	15.00	18.90	19.44	14.72	30.23	1.71	.....
Do.[1]	Aug. 3, 1936	.....	15.00	18.40	17.86	15.16	31.97	1.61	.....
Do.[1]	Aug. 14, 1936	.....	15.00	18.89	17.77	16.95	29.80	1.59	.....
Do.[1]	Sept. 3, 1936	.....	15.00	14.07	13.54	26.21	29.38	1.80	.....
Leonard [2]	July 3, 1936	.....	15.00	18.41	20.84	17.06	26.95	1.74	.....
Do.[2]	July 16, 1936	.....	15.00	18.90	19.44	14.72	30.23	1.71	.....
Do.[2]	Aug. 5, 1936	.....	15.00	13.99	13.71	21.68	34.31	1.31	.....
Do.[2]	Sept. 3, 1936	.....	15.00	14.54	14.72	22.84	31.27	1.63	.....

[1] This series from the same location along a dirt road.
[2] From very sandy soil, but not identical locations.

tant effect on the protein content. For instance, one of the four samples collected in 1934 compared favorably in protein with those collected in 1935 and 1936, but the other three had decidedly less. Crude fiber was lowest in the young, tender plants and highest in the more mature ones. No definite relationship between the ether extract or nitrogen-free extract and the maturity of the plant was apparent.

In the samples of 1934 the sample from Barrie contained approximately twice as much phosphorus as the sample from Bedford.

Analyses of stems and leaves were made on one sample cut July 1, 1936, and of stems, leaves, and flowering tips on a sample cut July 15, 1936. From the data obtained (table 2) it is clear that the stems

TABLE 2.—*Chemical composition of stems, leaves, and floral tips of Russian thistles collected in North Dakota, 1936*

Date collected	Description of sample	Water	Ash	Crude protein	Crude fiber	N-free extract	Ether extract
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
July 1, 1936	Stems	15.00	17.75	12.44	19.87	33.26	1.68
Do	Leaves	15.00	20.51	21.78	7.68	32.45	2.58
July 15, 1936	Stems	15.00	11.97	7.51	29.12	35.23	1.17
Do	Leaves	15.00	23.09	13.60	8.92	36.69	2.70
Do	Floral tips	15.00	16.70	23.15	9.34	34.07	1.74

were decidedly lower in ash, protein, and ether extract than the leaves and much higher in crude fiber. The nitrogen-free extract was nearly the same in the stems and leaves. The flowering tips contained 23.15 percent protein, which is higher than that in either stems or leaves. This table shows considerable variation in the composition of different parts of the plant and helps to explain

differences in lots of hay cut at different stages of maturity and in different places.

EXPERIMENTAL PROCEDURE

ANIMALS

Wether lambs from the experiment station flock were used in these trials. A new group of 12 wethers was used each year. The individual wethers are identified by the letters, A, B, C, etc., followed by a numeral, thus: A–36, A–37, etc.

COLLECTION OF EXCRETA

A set of 12 portable metabolism stalls, or cages, with heavy screen floors and drain pans for collecting the urine were built for these trials. The cages were large enough to permit the animals considerable freedom in getting up and down, but not large enough to permit them to turn about. The feces were collected in bags made from ordinary duck, lined with hospital rubber sheeting. The bags were held in place with a light harness.

WEIGHING AND SAMPLING OF FEEDS AND EXCRETA

Each portion of the ration was weighed to the nearest gram morning and night. At each weighing a definite portion was set aside to make the composite sample that would be used for chemical analysis at the end of the 10-day metabolism trial. In those trials in which silages were fed definite amounts of the silage were weighed and dried daily and composited at the end of the trial for the chemical sample. The 24-hour collections of feces and urine were accurately weighed. The total feces were air-dried in a bulk-sample drier (*9*) and sampled for analysis after grinding. When dried in the bulk-sample drier there was no appreciable loss of nitrogen. Aliquots of the fresh urine samples were composited daily for analysis at the end of the trial. The composite urine samples were preserved by the addition of toluene and storage in a refrigerator.

METHODS OF CHEMICAL ANALYSIS

The chemical analyses of feeds, feed residues, and feces were made by the official methods of the Association of Official Agricultural Chemists (*2*). For the determination of the mineral constituents in the urine, the samples were wet-ashed with nitric acid. Before taking the digestions to dryness the excess nitric acid was removed by addition of hydrochloric acid. The micro method was used for the determination of calcium. Before precipitation of the magnesium as magnesium ammonium phosphate, the calcium was removed as sulfate in alcohol. The term "protein" as used in this publication means the nitrogen times the factor 6.25.

The energy values of the feeds and excreta were determined with a Parr adiabatic oxygen-bomb calorimeter. Before combustion the urine was dried over sulfuric acid in vacuum desiccators and the caloric values were corrected for nitrogen lost on drying. As the urine had low caloric values, it was necessary to add pellets of known weight of benzoic acid of known caloric value in order to obtain complete combustion in the oxygen bomb. These pellets were added just prior to combustion of the sample.

SCHEDULE OF METABOLISM TRIALS

The metabolism trials included determinations of digestibility of rations; nitrogen, calcium, phosphorus, and magnesium balances; and energy determinations on feeds and visible excreta. The trials were 10 days in length, preceded by preliminary periods of 10 days or more. In spite of care in adjusting the rations to the appetites of the test animals before the trials were begun, there were appreciable feed residues in some instances.

To facilitate the general account of the trials and the identification of particular trials, a schedule giving the trial numbers, year of experiment, identification numbers of the test animals, and dates of preliminary feeding periods and metabolism trials are given in table 3.

TABLE 3.—*Schedule of metabolism trials*

Trial No.	Year of experiment	Sheep No.	Feeds	Transitional and preliminary periods [1]	Metabolism periods [1]
23	1936	A–36, B–36, C–36, D–36, E–36, F–36.	Russian-thistle hay, coarse	Feb. 4–16	Feb. 17–26.
24	1936	G–36, H–36, I–36, J–36, K–36.	Russian-thistle hay, fine	do	Do.
39	1937	G–37, H–37, I–37	Russian-thistles, ground, and cane molasses.[2]	Mar. 13–22	Mar. 23–Apr. 1.
33	1937	I–37, J–37, K–37	Russian-thistle-alfalfa silage	Jan. 13–25	Jan. 26–Feb. 4.
37	1937	A–37, B–37, C–37	Russian-thistle-molasses silage.	Mar. 13–22	Mar. 23–Apr. 1.
38	1937	D–37, E–37, F–37	Russian-thistle-phosphoric acid silage.	do	Do.

[1] Dates are inclusive. [2] Ground Russian-thistle hay, 5 parts; cane molasses, 1 part; water, 3 parts.

FEEDS USED IN TRIALS

A detailed description of the feeds used in these trials is given because Russian-thistles are not grown as a regular crop, but volunteer generously under droughty conditions. They are generally obtained from fields where seeded grain crops have failed to germinate or grow because of drought; along fences or restricted areas in fields. For this reason Russian-thistle hays are usually not "pure."

Coarse Russian-thistles.—These thistles were cut from the fence row of a cornfield, September 21 to 23, 1935. The growth was rank, and the stems were coarse, but the plants were still green at the time of cutting. A mechanical separation of the air-dried thistles indicated 83.5 percent of Russian-thistles, 9.0 percent of straw and grass, 0.6 percent of cornstalks, and 6.9 percent of miscellaneous weeds.

Fine Russian-thistles.—These thistles were cut September 27, 1935, on a plot from which a crop of crested wheat hay had been cut about the middle of July. They were much finer stemmed than the coarse thistles and were not nearly so tall at the time of cutting. This lot was also a purer fodder than the coarse thistles. A mechanical separation showed 93.5 percent of thistles and 6.5 percent of straw or crested wheat stems.

Russian-thistle hay, ground.—This hay was cut near Wheelock in Williams County, N. Dak., August 1, 1936, from a field that had been seeded to wheat, but in which the wheat had largely blown out or had failed to germinate. The thistles were cut and stacked rather loosely the same day in stacks about 10 to 12 feet wide. They were baled August 19 to 23 from the stack and shipped to the experiment station. The hay was very dry at the time of baling. The

mechanical separation showed about 90 percent of thistles and 10 percent of wheat straw containing a few heads of wheat. These thistles were a little coarser than the "fine" thistles grown at the experiment station, but they may be considered a fair sample of Russian-thistle hay.

Russian-thistle-alfalfa silage.—The thistles for this silage were from a field containing a very thin and scattered stand of alfalfa. The proportion of alfalfa to thistles varied in different parts of the field, and, therefore, the amount of alfalfa could not be estimated accurately. From observation of the different loads it was estimated that from 15 to 20 percent of the silage material was alfalfa, with a sprinkling of rough pigweed and prickly lettuce. Ground barley was added at the rate of about 85 pounds to the ton of wilted thistles. Water was also added. A small experimental cement stave silo, 8 feet in diameter and 25 feet high, was filled between August 15 and August 18, 1934. The thistles were soft and pliable, only a small proportion having hard, sharp spines. The silo was not opened until January 13, 1937. Much of the silage at the top and around the sides of the silo was spoiled, but the center contained some good, well-preserved silage, which was fed in trial 33. Another attempt at making silage from the thistles likewise resulted in much spoilage, and this also occurred in one case where molasses was added to the silage material. Evidently, from these trials and the experience of farmers, it is rather difficult to make good silage from Russian-thistles.

Russian-thistle-molasses silage.—On October 24, 1936, some silage was made from dry, chopped thistles by moistening them with water at the rate of 2 pounds of water to 1 pound of dry thistles and molasses at the rate of 70 pounds per ton of wet material. After mixing, the wet material was packed into galvanized iron cans 2 feet in diameter and 5 feet deep by tamping with a heavy iron. The cans were then sealed with waterproof paper and a layer of dirt on top and stored in a fairly warm basement until March 13, 1937, when the silage was used for the digestion trials. After removing about 1 foot of moldy silage at the top, a clean, dark-brown silage of good odor was reached. This silage was fed in trial 37.

Russian-thistle-phosphoric acid silage.—This silage was made on February 13, 1937, by moistening some of the dry, chopped Russian-thistles of the 1935 crop with water at the rate of 2 pounds per pound of the dry material and adding syrup of phosphoric acid at the rate of 10 pounds per ton of wet material. The same kind of cans were used as for the thistle-molasses silage. The cans were opened on March 13, 1937, and after about 1 foot of dirt and moldy silage had been removed from the top, good, well-preserved silage was reached. This was dark brown in color and appeared a little drier than normal silage. After opening, the silage tended to heat and mold more quickly than the silage made with molasses. This suggests that a larger amount of phosphoric acid should have been added. This silage was fed in trial 38.

CHEMICAL COMPOSITION AND GROSS ENERGY OF FEEDS

The chemical composition and gross energy of the feeds is given in table 4. To save space the analyses of feed residues and excreta are omitted.

TABLE 4.—*Chemical composition of Russian-thistle hays and silages*

Feeds	Trial No.	Year of experiment	Dry matter	Composition of dry matter								Energy per 100 pounds
				Ash	Crude protein	Crude fiber	N-free extract	Ether extract	Nitrogen	Calcium	Phosphorus	Magnesium	
			Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Therms*
Russian-thistle hay, coarse	23	1936	84.46	13.24	12.83	34.08	36.70	3.15	2.052	1.317	0.212	1.198	183.18
Russian-thistle hay, fine	24	1936	86.62	11.08	15.01	28.93	42.01	2.97	2.400	1.459	.204	1.873	180.93
Russian-thistle hay and molasses [1]	39	1937	55.36	15.36	12.62	20.35	50.06	1.61	2.020	2.758	.152	.904	170.67
Russian-thistle-alfalfa silage	33	1937	32.27	21.53	14.06	25.14	37.00	2.27	2.250	2.210	.174	1.110	175.51
Russian-thistle-molasses silage	37	1937	34.50	14.61	15.09	27.87	39.05	3.48	2.414	2.923	.209	1.586	181.89
Russian-thistle-phosphoric acid silage	38	1937	33.17	12.55	14.91	31.42	37.78	3.04	2.386	3.294	.573	1.852	194.37
Russian-thistle hay [2]	39	1937	87.24	16.72	14.39	23.30	44.19	1.41	2.303	[3] 1.875	[3] .915	.188	
Molasses, cane	39	1937	73.98	10.59	3.41	----------	86.00	----------	.546	1.959	.054	.431	162.12
				Composition of feeds as fed									
Russian-thistle hay, coarse	23	1936	84.46	11.18	10.84	28.78	31.00	2.66	1.733	1.112	0.179	1.012	154.71
Russian-thistle hay, fine	24	1936	86.62	9.60	13.00	25.06	36.39	2.57	2.079	1.264	.177	1.622	156.72
Russian-thistle hay and molasses [1]	39	1937	55.36	8.50	6.99	11.27	27.71	.89	1.118	1.527	.084	.500	94.48
Russian-thistle-alfalfa silage	33	1937	32.27	6.95	4.54	8.11	11.94	.73	.726	.713	.056	.358	56.44
Russian-thistle-molasses silage	37	1937	34.50	5.01	5.21	9.62	13.67	1.20	.833	1.008	.072	.547	62.65
Russian-thistle-phosphoric acid silage	38	1937	33.17	4.26	4.95	10.42	12.53	1.01	.791	1.093	.190	.617	61.16
Russian-thistle hay [2]	39	1937	87.24	14.59	12.55	20.33	38.55	1.23	2.009	[3] 1.636	[3] .164	[3] .796	
Molasses, cane	39	1937	73.98	7.83	2.52	----------	63.62	----------	.404	1.451	.040	.319	119.94

[1] As fed; ground Russian-thistles, 5 parts; cane molasses, 1 part; water, 3 parts.
[2] Through a misunderstanding, no separate sample of the thistles was taken in trial 39. These analyses are the average of 2 other samples from the same lot of hay.
[3] The mineral analysis is from a single sample on the same lot of hay.

RATIONS AND WATER CONSUMED

Table 5 shows the amount of feed offered to each sheep during the trial, the amount of the feed residues, and the water drunk. This is given in place of a more detailed table showing how much of each nutrient was consumed, excreted, and digested. The more detailed table is omitted to save space.

TABLE 5.—*Average rations offered, feed residues, and water drunk during metabolism trials*

Trial No.	Year of experiment	Ration, residues, and water	Sheep No.					
			A-36	B-36	C-36	D-36	E-36	F-36
23	1936	Russian-thistles, coarse grams	250.0	280.0	200.0	250.0	320.0	320.0
		Uneaten feed residues do	12.4	11.2	70.0	8.9	4.3	3.6
		Water drunk do	485.0	417.0	503.0	608.0	803.0	748.0
			Sheep No.					
			G-36	H-36	I-36	J-36	K-36	L-36
24	1936	Russian-thistles, fine do	280.0	200.0	250.0	200.0	200.0	None
		Uneaten feed residues do	.7	1.2	24.9	1.9	18.6	None
		Water drunk do	662.0	526.0	608.0	594.0	626.0	962.0
						Sheep No.		
						G-37	H-37	I-37
39	1937	Russian-thistles, ground, 5 parts; molasses, 1 part; water, 3 parts do				1,200.0	1,100.0	700.0
		Uneaten feed residues do				7.8	.6	.7
		Water drunk do				2,127.0	2,046.0	1,610.0
						Sheep No.		
						I-37	J-37	K-37
33	1937	Russian-thistle-alfalfa silage do				1,100.0	1,300.0	1,400.0
		Uneaten feed residues do				99.4	1.5	1.0
		Water drunk do				748.0	2,046.0	2,799.0
						Sheep No.		
						A-37	B-37	C-37
37	1937	Russian-thistle-molasses silage do				700.0	1,200.0	800.0
		Uneaten feed residues do				5.6	.1	.5
		Water drunk do				726.0	494.0	1,275.0
						Sheep No.		
						D-37	E-37	F-37
38	1937	Russian-thistle-phosphoric acid silage do				700.0	800.0	600.0
		Uneaten feed residues do				3.9	46.5	3.7
		Water drunk do				608.0	1,170.0	572.0

It was found that the sheep would not eat the dry, chopped thistles, and, therefore, in trials 23 and 24, the morning and evening portions were weighed into 25-pound lard cans, sprinkled with distilled water, and allowed to soak until the next day. Even when thus soaked,

the sheep ate only from 200 to 320 gm. of the dry thistles per head daily, which was not enough to maintain their weight.

In trial 39 the ground thistles were moistened with cane molasses and water in the proportions of 5 parts of thistles, 1 part of molasses, and 3 parts of water. With this treatment, the sheep ate from 389 to 667 gm. of thistles and from 78 to 133 gm. of molasses per head daily. Sheep I–37, which ate the smallest amounts, lost a little weight during the trial, but the other two sheep gained a little. In trials 33, 37, and 38 all the sheep lost weight, indicating that the rations were unpalatable and that not enough was eaten for maintenance.

The water drunk by the sheep was from the Fargo water system. Daily samples were taken to form a composite sample for analysis. The analyses for calcium and magnesium are given in table 6. The analyses failed to show any phosphorus in the water.

TABLE 6.—*Calcium and magnesium in drinking water*

Feeds	Trial No.	Year of experiment	Minerals in water [1]	
			Calcium	Magnesium
			P. p. m.	*P. p. m.*
Russian-thistle hay, coarse	23	1936	18.7	65.1
Russian-thistle hay, fine	24	1936	18.7	65.1
Russian-thistle hay, ground, and molasses	39	1937	10.7	58.7
Russian-thistle-alfalfa silage	33	1937	17.1	45.2
Russian-thistle-molasses silage	37	1937	10.7	58.7
Russian-thistle-phosphoric acid silage	38	1937	10.7	58.7

[1] No phosphorus was present in the water.

RESULTS OF METABOLISM TESTS

APPARENT DIGESTIBILITY OF FEEDS

The percentage apparent digestibility of the feeds, as determined by the individual sheep in the different trials, is given in table 7. The average coefficients are summarized in table 8.

TABLE 7.—*Percentage apparent digestibility of feeds*

Trial No.	Sheep No.	Feeds	Dry matter	Organic matter	Crude protein	Crude fiber	N-free extract	Ether extract
			Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
	A–36		51.2	52.1	70.0	40.6	53.8	73.9
	B–36		46.9	47.3	67.5	33.0	50.5	76.4
23	C–36	Russian-thistle hay, coarse	54.1	53.4	67.6	41.8	55.2	79.0
	D–36		45.2	44.9	64.4	31.2	47.7	75.8
	E–36		47.6	48.8	63.9	36.6	52.9	70.2
	F–36		44.7	44.2	66.2	31.7	45.6	73.8
	G–36		44.5	47.7	66.4	32.0	50.5	65.0
	H–36		46.6	49.4	68.0	34.3	51.7	68.6
24	I–36	Russian-thistle hay, fine	48.6	50.8	67.1	35.2	54.3	70.7
	J–36		46.7	49.6	68.6	37.5	50.0	64.7
	K–36		48.4	52.3	66.5	38.4	54.9	70.8
	G–37		61.8	61.9	64.4	44.8	68.0	64.2
39	H–37	Russian-thistle hay, ground, and molasses.[1]	61.3	61.3	64.5	41.0	68.5	71.4
	I–37		62.9	63.1	65.0	44.9	70.0	66.1
	I–37		50.0	48.1	36.8	48.6	51.8	50.0
33	J–37	Russian-thistle-alfalfa silage [2]	49.5	46.9	35.0	46.7	51.4	49.5
	K–37		50.8	48.0	39.9	46.5	52.1	48.5
	A–37		43.3	42.9	59.6	31.4	41.7	75.6
37	B–37	Russian-thistle-molasses silage [3]	41.6	42.4	60.3	30.5	41.6	70.1
	C–37		44.1	45.8	62.9	32.2	45.8	80.2
	D–37		39.2	41.6	58.1	31.7	40.1	81.4
38	E–37	Russian-thistle-phosphoric acid silage [4]	35.0	37.0	50.4	29.1	34.6	80.0
	F–37		38.7	41.0	58.2	33.1	34.5	80.0

[1] Ground Russian-thistle hay, 5 parts; cane molasses, 1 part; water 3 parts.
[2] The fresh silage material contained some alfalfa, estimated at about 15 percent by weight.
[3] Molasses was added at the rate of about 70 pounds per ton of wet material.
[4] Phosphoric acid was added at the rate of 10 pounds per ton of wet material.

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TABLE 8.—*Coefficients of apparent digestibility of Russian-thistle hays and silages*

Feeds	Trial No.	Individual trials	Year of experiment	Dry matter	Organic matter	Crude protein	Crude fiber	N-free extract	Ether extract
		Number		*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Russian-thistle hay, coarse	23	6	1936	47.6	47.8	66.4	35.1	50.4	74.6
Russian-thistle hay, fine	24	5	1936	46.8	49.8	67.3	35.2	52.2	67.9
Russian-thistle hay ground and molasses [1]	39	3	1937	61.9	62.0	64.6	43.4	68.7	67.3
Russian-thistle-alfalfa silage	33	3	1937	50.2	47.6	37.4	47.0	51.8	49.2
Russian-thistle-molasses silage	37	3	1937	42.8	43.5	60.9	31.2	42.9	74.5
Russian-thistle-phosphoric acid silage	38	3	1937	37.6	39.8	55.4	31.2	37.4	80.5

[1] Ground Russian-thistle hay, 5 parts; cane molasses, 1 part; water 3 parts.

The average digestion coefficients for the coarse and fine Russian-thistles do not differ greatly. Except for a slightly lower coefficient for dry matter (difference −0.8), and for ether extract (−6.7), all the coefficients are slightly higher for the fine thistles, with differences as follows: Organic matter, +2.0; protein, +0.9; fiber, +0.1; and nitrogen-free extract, +1.8.

It is not possible to observe directly the effect of molasses upon the digestibility of the thistles, since the thistles fed in trial 39 were from a different crop. However, the coefficients for dry matter, organic matter, crude fiber, and nitrogen-free extract are higher, and the protein and ether extract are somewhat lower than they are for the thistles without the molasses.

Compared to the Russian-thistle hay, the Russian-thistle-alfalfa silage shows higher digestibility for dry matter and crude fiber, with approximately the same digestibility of organic matter and nitrogen-free extract, but decidedly lower digestibility of protein and ether extract. Apparently, ensiling and storing the material for about 2½ years had the effect of greatly reducing the digestibility of the protein. (See table 7.)

The Russian-thistle-molasses silage shows somewhat lower coefficients of digestibility than the hay in trial 24 for all nutrients except ether extract. The effect of the molasses and ensiling was to lower the digestibility of the fine thistles.

The Russian-thistle-phosphoric-acid silage, made from the same lot of thistles as the thistle-molasses silage, gave lower coefficients for dry matter, organic matter, crude protein, and nitrogen-free extract, but identical coefficients for crude fiber and higher digestibility for ether extract. It might be inferred from this that the phosphoric acid had, in general, a depressing effect on digestibility. In other tests at this station on leafy spurge there was no such effect, and, therefore, such a conclusion is not justified at this time.

NITROGEN BALANCES

Table 9 gives the nitrogen balances of the individual sheep during the trials. These balances were obtained in order to determine the condition of the sheep while on experiment and to furnish data for the calculation of metabolizable energy. Only two sheep had positive nitrogen balances.

TABLE 9.—*Daily nitrogen balance of the experimental sheep*

Trial No.	Sheep No.	Feeds	Nitrogen in—			Nitrogen balance
			Feeds	Feces	Urine	
			Grams	*Grams*	*Grams*	*Grams*
23	A-36	Russian-thistle hay, coarse	4.20	1.27	5.68	−2.75
	B-36		4.73	1.53	5.44	−2.24
	C-36		2.32	.75	4.60	−3.03
	D-36		4.22	1.50	5.09	−2.37
	E-36		5.49	1.99	6.42	−2.92
	F-36		5.49	1.85	6.34	−2.70
24	G-36	Russian-thistle hay, fine	5.81	1.95	6.12	−2.26
	H-36		4.14	1.33	5.48	−2.67
	I-36		4.63	1.51	5.63	−2.51
	J-36		4.13	1.30	5.71	−2.88
	K-36		3.82	1.28	5.29	−2.75
39	G-37	Russian-thistle hay, ground, and molasses	13.32	4.74	6.99	+1.59
	H-37		12.29	4.37	6.85	+1.07
	I-37		7.82	2.74	5.21	−.13
33	I-37	Russian-thistle-alfalfa silage	6.14	3.88	4.71	−2.45
	J-37		9.41	6.11	7.41	−4.11
	K-37		10.15	6.10	7.77	−3.72
37	A-37	Russian-thistle-molasses silage	5.71	2.30	4.06	−.65
	B-37		9.99	3.96	6.37	−.34
	C-37		6.65	2.46	4.58	−.39
	D-37		5.46	2.29	4.33	−1.16
38	E-37	Russian-thistle-phosphoric acid silage	5.41	2.68	4.37	−1.64
	F-37		4.70	1.96	4.55	−1.81

METABOLIZABLE ENERGY IN FEEDS AND RATIONS

The gross energy in the feed, feces, and urine was determined directly by means of a Parr adiabatic oxygen-bomb calorimeter. The energy in methane was computed by the method of Armsby (*1*) according to which 100 gm. of digestible carbohydrates produce 4.5 gm. of methane having an energy value of 60.1 large calories. The energy in the urine was corrected for gain or loss of protein by the use of Rubner's value for protein nitrogen as employed by Armsby (*1*). The energy data on all the rations are given in table 10.

From a study of the values obtained by various investigators, Armsby (*1*) found that the metabolizable energy per pound of digestible organic matter ranged from 1.50 to 1.70 therms per pound of digestible organic matter for roughages, with an average of 1.60 therms; for mixed rations, the values ranged from 1.58 to 1.87 therms, with an average of 1.66 therms. Christensen and Hopper (*7*), in trials with cattle, found a range of 1.67 to 1.81 therms per pound of digestible organic matter in 25 trials on roughages and a range of 1.72 to 1.84 therms on mixed rations. The average was 1.737 therms for the roughages and 1.767 for the mixed rations. On two prairie hays Christensen and Hopper (*6*) found the metabolizable energy per pound of digestible organic matter to be 1.432 and 1.514 therms. Similar low values have also been found on certain other feeds (unpublished data).

As shown in table 10, the metabolizable energy per pound of digestible organic matter ranges from 1.465 to 1.796 therms, with an average of 1.614 therms. It is not clear why the coarse thistles gave an average of 1.630 therms of metabolizable energy per pound of digestible organic matter and the fine thistles a lower value of 1.528 therms. On a dry basis the coarse thistles contained 13.24 percent of ash and 183.18 therms of metabolizable energy per 100 pounds, as compared to 11.08

TABLE 10.—*Gross energy of rations, losses in excreta, and metabolizable energy*

Trial No.	Sheep No.	Feeds	Energy in rations and excreta									Metabolizable energy—	
			Gross energy of feed	Losses—			Metabolizable	Percentage losses of energy—			Metabolizable energy	Per pound of digestible organic matter	Per pound of digestible nutrients
				In feces	In urine	As methane		In feces	In urine	As methane			
			Therms	*Therms*	*Therms*	*Therms*	*Therms*	*Percent*	*Percent*	*Percent*	*Percent*	*Therms*	*Therms*
23	A–36	Russian-thistle hay, coarse	0.803	0.400	0.042	0.040	0.321	49.81	5.23	4.98	39.98	1.621	1.514
	B–36		.910	.497	.041	.040	.332	54.62	4.51	4.39	36.48	1.636	1.516
	C–36		.415	.197	.028	.021	.169	47.47	6.75	5.06	40.72	1.623	1.496
	D–36		.818	.463	.042	.034	.279	56.60	5.13	4.16	34.11	1.599	1.484
	E–36		1.075	.597	.050	.051	.407	52.74	4.65	4.74	37.86	1.636	1.536
	F–36		1.077	.606	.050	.044	.377	56.27	4.64	4.09	35.00	1.672	1.551
		Average						52.92	5.15	4.57	37.36	1.630	1.516
24	G–36	Russian-thistle hay, fine	.964	.523	.049	.044	.348	54.25	5.08	4.56	36.10	1.540	1.456
	H–36		.686	.361	.038	.033	.254	52.62	5.54	4.81	37.03	1.530	1.392
	I–36		.774	.397	.047	.039	.291	51.29	6.07	5.04	37.60	1.499	1.415
	J–36		.683	.352	.038	.033	.260	51.54	5.56	4.83	38.07	1.562	1.477
	K–36		.621	.309	.039	.032	.241	49.76	6.28	5.15	38.81	1.508	1.418
		Average						51.89	5.71	4.88	37.52	1.528	1.432
39	G–37	Russian-thistle hay, ground, with molasses	2.471	1.007	.147	.170	1.147	40.75	5.95	6.88	46.42	1.512	1.476
	H–37		2.289	.970	.135	.156	1.028	42.38	5.90	6.82	44.91	1.476	1.436
	I–37		1.455	.591	.094	.103	.667	40.62	6.46	7.08	45.84	1.465	1.428
		Average						41.25	6.10	6.93	45.72	1.484	1.447
33	I–37	Russian-thistle-alfalfa silage	1.024	.543	.042	.049	.390	53.03	4.10	4.79	38.09	1.787	1.726
	J–37		1.618	.883	.070	.077	.588	54.57	4.33	4.76	36.34	1.733	1.670
	K–37		1.745	.923	.066	.084	.672	52.89	3.78	4.81	38.51	1.791	1.728
		Average						53.50	4.07	4.79	37.65	1.770	1.708
37	A–37	Russian-thistle-molasses silage	.947	.537	.044	.036	.330	56.71	4.65	3.80	34.85	1.728	1.587
	B–37		1.657	.929	.072	.062	.594	56.07	4.35	3.74	35.85	1.796	1.655
	C–37		1.103	.597	.049	.044	.413	54.13	4.44	3.99	37.44	1.736	1.595
		Average						55.64	4.48	3.84	36.05	1.753	1.612
38	D–37	Russian-thistle-phosphoric acid silage	.930	.564	.046	.035	.285	60.65	4.95	3.76	30.65	1.563	1.439
	E–37		.907	.589	.048	.030	.240	64.94	5.29	3.31	26.46	1.515	1.379
	F–37		.795	.479	.039	.029	.248	60.25	4.91	3.65	31.19	1.609	1.485
		Average						61.95	5.05	3.57	29.43	1.562	1.434

percent of ash and 180.93 therms of energy in the fine thistles. The ground Russian-thistles with molasses showed the lowest value of all, 1.484 therms per pound of digestible organic matter. No explanation

TABLE 11.—*Dry matter, digestible crude protein, total digestible nutrients, and metabolizable energy in 100 pounds of feed as fed and in dry matter (on apparent digestibility basis)*

Feeds	Trial No.	Individual trials	Year of experiment	As fed					In dry matter		
				Dry matter	Digestible crude protein	Total digestible nutrients	Nutritive ratio 1:	Metabolizable energy	Digestible crude protein	Total digestible nutrients	Metabolizable energy
		Number		*Percent*	*Percent*	*Percent*		*Therms*	*Percent*	*Percent*	*Therms*
Russian-thistle hay, coarse	23	6	1936	[1]84.46	7.2	37.4	4.2	57.80	8.5	44.3	68.44
Russian-thistle hay, fine	24	5	1936	[1]86.62	8.7	40.5	4.6	58.80	10.1	46.7	67.88
Russian-thistle hay, ground, with molasses	39	3	1937	55.36	4.5	29.8	6.6	43.20	8.2	53.8	78.03
Russian-thistle-alfalfa silage	33	3	1937	32.37	1.7	12.5	6.3	21.32	5.3	38.8	66.08
Russian-thistle-molasses silage	37	3	1937	34.50	3.2	14.0	3.4	22.58	9.2	40.5	65.46
Russian-thistle-phosphoric acid silage	38	3	1937	33.17	2.8	12.5	3.5	18.00	8.3	37.7	54.26

[1] On air-dry basis; not including water used in moistening thistles.

for this is apparent, since the total digestible nutrients are high (table 11).

The metabolizable energy per pound of total digestible nutrients in these trials ranges from 1.379 to 1.728 therms, with an average of 1.516. This is a little lower than the average value of 1.616 therms reported by Kriss (*10*).

DIGESTIBLE NUTRIENTS IN FEEDS AND RATIONS

The results of the several trials to determine digestible nutrients and metabolizable energy in the feeds are summarized in table 11. For convenience in using the data and making comparisons, the digestible nutrients and metabolizable energy are given for the feeds as fed as well as on a dry-matter basis.

Morrison's (*13*) average of all analyses for red clover hay, computed to a dry basis, is 7.9 percent of digestible protein and 58.8 percent of total digestible nutrients. From this it is evident that the Russian-thistle hay contains more digestible protein than does red clover hay, but about 12 to 14 percent less of total digestible nutrients.

Christensen and Hopper (*7*), in seven individual trials on corn silage, found 5.3 percent of digestible protein and 69.7 percent of total digestible nutrients on a dry basis. Morrison's (*13*) average of all analyses, computed to dry basis, is 4.6 percent digestible protein and 66.1 percent of total digestible nutrients. The total digestible nutrients in the three Russian-thistle silages range from 37.7 to 40.5 percent, which is considerably lower than in the corn silage. The digestible protein in the thistle silages ranges from 5.3 to 9.2 percent, which is, in general, somewhat higher than that in corn silage.

The metabolizable energy in the two thistle hays and silages is similar except for the thistle-phosphoric-acid silage, which is con-

siderably lower on an air-dry basis. This low value is due to the relatively large loss of energy in the feces (table 10).

An important consideration in evaluating any feed is its palatability and bulkiness. If a feed is unpalatable, an animal may not eat enough for its needs, or, if it is too bulky, the animal may lack capacity for consuming enough to meet its requirements. In these trials the Russian-thistle hays and silages proved rather unpalatable. In only two instances did the sheep eat enough to show a gain in weight, and that was on the ground thistles with molasses. Data on the average live weights, average daily gains or losses, and the dry matter, digestible protein, total digestible nutrients, and metabolizable energy in the rations are presented in table 12.

Brody, Procter, and Ashworth (*4*) give the maintenance requirement of a 100-pound sheep as 59 gm. of digestible protein, 572 gm., or 1.261 pounds, of total digestible nutrients, and 2.282 therms of energy, presumably metabolizable, on the basis of 1 pound of total digestible nutrients as equivalent to 1,812 calories. Kriss (*10*) gives 1.616 therms of metabolizable energy per pound of total digestible nutrients as the average value for mixed rations of cows. If we multiply 1.261 pounds of total digestible nutrients by 1.616, the requirement for metabolizable energy becomes 2.038 therms.

On the basis of either of the foregoing requirements, none of the sheep received enough total digestible nutrients or metabolizable energy for maintenance; yet sheep G–37 and H–37 in trial 39 showed some gains during the trial. Armsby (*1*) reviewed the available data and estimated the maintenance requirement of metabolizable energy from respiration experiments as 1.322 therms and from live weight experiments as 1.368 therms. Mitchell, Kammlade, and Hamilton (*11*) found the maintenance requirement for metabolizable energy in one series of trials with sheep to be 1.864 therms on alfalfa, 1.521 on clover, and 1.507 on timothy hay. In another series they found the requirement to be 1.382 therms for alfalfa and 1.149 for timothy hay.

From 11 respiration trials at the New Hampshire Experiment Station, Ritzman [4] estimates the maintenance requirement of adult sheep at 1.686 therms per 100 pounds of live weight. If five experiments at low temperatures are omitted, the figure becomes 1.820 therms. These lower values probably come closer to the actual requirements for sheep confined in metabolism cages than the higher values, but, even so, the sheep on the Russian-thistle hays alone (trials 23 and 24) ate only about one-fourth to one-third as much as was necessary for maintenance.

Two of the three sheep on ground Russian-thistles moistened with diluted molasses (trial 39) ate enough to show some gains, and they were the only ones that received enough protein to show positive nitrogen balances (table 9).

The sheep on the Russian-thistle-alfalfa silage (trial 33) and those on the thistle-molasses silage (trial 37) in general consumed somewhat more of the total digestible nutrients and metabolizable energy than those on the Russian thistles alone, indicating that these silages were somewhat more palatable. Those on the Russian-thistle-phosphoric

[4] Personal communication from E. G. Ritzman, formerly research professor of animal husbandry, New Hampshire Agricultural Experiment Station.

TABLE 12.—*Live weights, digestible nutrients, and metabolizable energy in rations and per hundred pounds live weight*

TABLE 12.—*Live weights, digestible nutrients, and metabolizable energy in rations and per hundred pounds live weight*

Trial No.	Sheep No.	Feeds	Live weight	Average daily gain or loss	Feed consumed per day per head					Feed consumed per hundred pounds live weight (W ²/³)				
					Dry matter	Digestible protein	Total digestible nutrients	Nutritive ratio 1:	Metabolizable energy	Dry matter	Digestible protein	Total digestible nutrients	Metabolizable energy	
			Pounds	*Pounds*	*Grams*	*Grams*	*Grams*		*Therms*	*Grams*	*Grams*	*Grams*	*Therms*	
23	A–36	Russian-thistle hay, coarse	85.0	−0.50	199.5	18.4	96.2	4.2	0.321	224.9	20.7	103.3		0.361
	B–36		71.6	−.56	226.0	19.9	99.2	4.0	.332	288.5	25.4	126.6		.424
	C–36		67.9	−.59	103.6	9.8	51.3	4.2	.169	137.5	13.0	68.1		.224
	D–36		66.6	−.56	202.9	17.0	85.2	4.0	.279	273.1	22.9	114.7		.375
	E–36		82.7	−.47	266.3	21.9	120.0	4.5	.407	305.9	25.2	137.8		.465
	F–36		76.2	−.53	266.9	22.7	110.0	3.9	.377	325.4	27.7	134.1		.490
		Average								259.2	22.5	114.9		.385
24	G–36	Russian-thistle hay, fine	69.8	−.59	241.8	24.1	108.5	3.5	.348	314.4	31.3	141.1		.455
	H–36		63.7	−.47	172.1	17.6	79.9	3.5	.254	239.2	24.5	111.1		.353
	I–36		80.6	−.56	193.9	19.4	93.0	3.8	.291	227.0	22.7	108.9		.341
	J–36		73.8	−.59	171.4	17.7	79.7	3.5	.260	214.0	22.1	99.5		.325
	K–36		73.8	−.63	156.2	15.9	76.9	3.8	.241	223.0	22.7	109.8		.344
		Average								243.5	24.7	114.1		.364
30	G–37	Russian-thistle hay, ground, with molasses	69.5	+.18	657.0	53.6	352.3	5.6	1.147	856.9	69.9	459.5		1.496
	H–37		71.5	+.28	908.4	49.5	324.7	5.6	1.028	777.4	63.3	414.9		1.314
	I–37		75.0	−.11	386.8	31.7	211.8	5.7	.667	477.1	39.1	261.3		.823
		Average								703.8	57.4	378.6		1.211
33	I–37	Russian-thistle-alfalfa silage	72.7	−.29	261.2	14.1	102.3	6.3	.390	320.7	17.8	129.1		.492
	J–37		96.9	−.02	418.1	20.6	159.8	6.8	.588	403.3	22.8	177.1		.623
	K–37		82.5	−.19	460.9	25.3	176.3	6.0	.672	518.9	29.1	202.9		.773
		Average								437.3	23.2	169.7		.639
37	A–37	Russian-thistle-molasses silage	45.5	−.08	236.4	21.2	94.4	3.5	.330	420.1	37.7	167.7		.586
	B–37		56.5	−.13	414.0	37.7	162.8	3.3	.594	628.1	57.3	247.0		.901
	C–37		43.4	−.10	275.5	26.1	117.4	3.5	.413	506.7	48.0	215.9		.760
		Average								518.3	47.6	210.2		.749
38	D–37	Russian-thistle-phosphoric acid silage	55.2	−.18	228.6	19.8	90.0	3.6	.285	352.8	30.6	138.9		.440
	E–37		61.0	−.35	223.9	17.1	79.1	3.0	.240	310.7	24.5	113.5		.344
	F–37		67.2	−.33	165.6	17.1	75.9	3.4	.248	291.0	25.7	114.1		.373
		Average								322.2	26.9	122.2		.386

acid silage (trial 38) consumed about the same amounts of total digestible nutrients and metabolizable energy as those on the hays alone, indicating that this silage was less palatable than the other two.

It might appear from the data of table 12 that the Russian-thistles are of little or no value as feed for sheep. However, in another phase of this project bred ewes fed chopped Russian-thistles moistened with water and molasses as the only, or principal, roughage, supplemented with barley, produced healthy, vigorous lambs (unpublished data). The metabolism trials show that the Russian-thistles have considerable nutritive value, which can be utilized in times of feed emergency.

CALCIUM, PHOSPHORUS, AND MAGNESIUM BALANCES

Although this project was not planned to determine the mineral requirements of sheep, it seemed desirable to obtain information on the utilization of calcium, phosphorus, and magnesium along with the other data. Table 13 gives the data on the intake, excretion, and balances for calcium, phosphorus, and magnesium, calculated in direct proportion to 100 pounds live weight.

The intake of calcium of the sheep on the Russian-thistle hays ranged from 2.174 to 5.066 gm., and all showed negative calcium balances except sheep C–36, which received the smallest amount of calcium. These sheep also showed negative balances for phosphorous on an intake ranging from 0.353 to 0.749 gm. The sheep on the coarse thistles received from 1.977 to 4.288 gm. of magnesium, and all had negative balances except sheep C–36, which received the smallest amount of magnesium. The sheep on the fine thistles, in general, received a little higher level of magnesium, the amounts ranging from 4.334 to 6.545 gm. At this level all had positive balances except sheep J–36.

The three sheep on the ground Russian-thistles with molasses, (trial 39) consumed more feed than the others, and all showed positive balances for calcium, phosphorous, and magnesium.

On the Russian-thistle-alfalfa silage (trial 33) the calcium intake ranged from 9.241 to 12.148 gm., and all the sheep had positive balances. The phosphorous ranged from 0.642 to 0.952 gm., with negative balances for all three sheep. The magnesium ranged from 4.640 to 6.225 gm., and, curiously, sheep I–37, which received the smallest amount of magnesium, showed a positive balance while the other two were negative.

In trial 37, on Russian-thistle-molasses silage, the calcium intake ranged from 15.215 to 21.427 gm. Sheep A–37, on the lower level of calcium, gained 1.039 gm.; whereas, sheep B–37, which received 21.427 gm. of calcium, gained only 0.011 gm, and sheep C–37, on 18.588 gm. of calcium, lost 0.329 gm. Why this group showed such mixed results is not clear. All the sheep in this group had positive phosphorous and magnesium balances.

The sheep on the Russian-thistle-phosphoric acid silage (trial 38), with calcium intakes ranging from 11.332 to 13.678 gm., showed larger positive balances than the sheep in trial 33 on similar intakes of calcium. The phosphorus intake by this group was the highest of any, and two of the sheep showed positive balances. However.

TABLE 13.—*Daily calcium, phosphorus, and magnesium balances of sheep calculated in direct proportion to 100 pounds of live weight*

Trial No.	Sheep No.	Feeds	Calcium				Phosphorus				Magnesium			
			Intake in feed and water	Outgo in—		Balance	Intake in feed and water	Outgo in—		Balance	Intake in feed and water	Outgo in—		Balance
				Feces	Urine			Feces	Urine			Feces	Urine	
			Grams	*Grams*	*Gram*	*Grams*	*Grams*	*Grams*	*Gram*	*Gram*	*Grams*	*Grams*	*Grams*	*Gram*
23	A-36	Russian-thistle hay, coarse	3.212	3.175	0.076	−0.039	0.514	0.639	0.099	−0.224	2.944	2.906	0.336	−0.298
	B-36		3.248	3.306	.101	−.159	.681	.057	.039	−.415	3.888	.607	.321	−.101
	C-36		2.174	4.021	.063	−1.910	.353	.202	.575	−.424	1.977	1.534	.321	+.122
	D-36		2.088	2.678	.090	−.580	.655	1.003	.003	−.351	3.746	3.247	.800	−.301
	E-36		4.271	4.268	.075	−.072	.684	.980	.005	−.301	3.923	3.439	.651	−.167
	F-36		4.668	4.694	.088	−.114	.749	.969	.096	−.306	4.288	4.064	.580	−.356
	G-36		5.066	6.358	.077	−1.369	.706	.970	.041	−.305	6.545	6.023	.482	+.040
	H-36		3.951	4.390	.094	−.533	.550	.696	.119	−.265	5.111	4.051	.877	+.183
24	I-36	Russian-thistle hay, fine	3.421	3.464	.073	−.116	.485	.661	.005	−.181	4.560	3.863	.478	+.219
	J-36		3.410	4.106	.069	−.757	.474	.570	.278	−.374	4.419	4.137	.530	−.248
	K-36		3.100	3.633	.074	−.598	.443	.994	.011	−.562	4.334	3.522	.670	+.942
	L-36		26.115	20.459	.151	+5.505	1.439	.968	.023	+.448	8.768	7.237	.898	+.633
39	H-37	Russian-thistle hay, ground, with molasses	23.499	17.508	.138	+5.853	1.294	.912	.018	+.364	7.963	6.618	.727	+.518
	I-37		14.247	10.331	.108	+3.808	.784	.606	.011	+.165	4.792	4.020	.583	+.189
	J-37		9.241	8.572	.144	+.525	.642	.949	.025	−.332	4.640	4.164	.276	+.200
33	K-37	Russian-thistle-alfalfa silage	10.660	10.456	.007	+.136	.838	.918	.167	−.247	5.455	5.304	.690	−.589
	L-37		12.148	11.429	.102	+.617	.952	.605	.556	−.209	6.225	5.022	.847	−.244
37	A-37	Russian-thistle-molasses silage	15.215	14.121	.055	+1.039	1.088	.536	.007	+.545	8.345	7.169	.681	+.495
	B-37		21.427	21.342	.074	+.011	1.531	1.437	.011	+.083	11.673	10.186	1.067	+.420
	C-37		18.588	18.809	.106	−.329	1.327	1.251	.014	+.062	10.242	8.962	1.000	+.251
	D-37		13.678	10.719	.065	+2.894	2.380	2.509	.009	−.138	7.743	6.529	.634	+.580
38	E-37	Russian-thistle-phosphoric acid silage	11.874	10.064	.103	+1.707	2.149	1.334	.515	+.300	6.992	6.495	.272	+.225
	F-37		11.332	9.178	.100	+2.054	1.970	1.538	.329	+.103	6.434	5.867	.533	+.034

sheep D–37, which received the largest amount of phosphorus of any in the trials, had a negative balance. All three of the sheep in this group had positive magnesium balances.

Mitchell and McClure (*12*) reviewed the mineral requirements of farm animals on the basis of available data and reached the conclusion that ewe lambs weighing from 50 to 110 pounds would require 1.40 gm. of calcium and 1.34 gm. of phosphorus and that ram lambs weighing from 50 to 120 pounds would require 1.59 gm. of calcium and 1.48 gm. of phosphorus. No requirements for magnesium were given.

If the figures of Mitchell and McClure are used as a basis for comparison, it is evident that all the sheep received considerably more calcium than the indicated requirements; yet, a considerable number of negative balances were observed. In trial 33, where the calcium intake ranged from 9.241 to 12.148 gm., small positive balances were obtained, but in trial 38, where the calcium intakes ranged from 11.332 to 13.678 gm., the positive balances were notably higher. This suggests a possible difference in the availability of the calcium in the two feeds. In the series as a whole, with one exception, positive calcium balances were obtained only where more than 10 gm. of calcium were fed per hundred pounds of live weight.

Comparing the phosphorus balances in the same way, it is observed that, where more than 1 gm. of phosphorus was consumed, the balances were positive, except for the erratic result from sheep D–37 in trial 38. This would indicate that the requirements for phosphorus suggested by Mitchell and McClure should be adequate.

A consideration of the magnesium balances shows 8 negative balances out of 23 trials. Two sheep, J–37 on 5.455 gm. and K–37 on 6.225 gm. of magnesium, showed negative balances, but the other 6 negative balances were on intakes of less than 4.640 gm. of magnesium. On intakes from 4.640 gm. to 11.673 gm. of magnesium, the balances were all positive—except as noted. From the data obtained, it appears that approximately 4.5–5 gm. daily intake of magnesium per 100 pounds of live weight was needed to meet the maintenance requirements of lambs under the above-described conditions. The low digestibility of the Russian-thistle possibly accounts for the poor utilization of the magnesium present in the ration.

It is evident that calcium, phosphorus, and magnesium may be stored by sheep on rations that are below the maintenance requirements in protein and total digestible nutrients or energy. How much, if at all, the intakes of these elements might be lowered and still give positive balances on rations adequate in protein and energy is not indicated by these trials.

DISCUSSION OF RESULTS

The Russian-thistle has been used for years in the Great Plains area as an emergency feed, particularly for cattle. By its use farmers have been enabled to keep livestock through winter seasons when otherwise they would have had to sell off stock or suffer heavy losses because of an inadequate feed supply. The composition of the thistles and the

results of the metabolism trials show that the thistles compare favorably with red clover hay in digestible protein and that they furnish nearly as much digestible nutrients as oat straw and more than wheat straw on the basis of Morrison's (*13*) tables. According to Morrison, oat straw on a dry basis contains 49.2 and wheat straw 39.6 percent of total digestible nutrients, as compared to 44.3 percent in the "coarse" thistles and 46.7 percent in the "fine" thistles.

It is evident, therefore, that, if enough is eaten, and if the thistles have no injurious effects on the animals, Russian-thistles should prove a valuable feed in times of emergency. The writers' experience is that the cured thistles are unpalatable to sheep and that moistening them with water alone is not sufficient to induce the sheep to eat enough for maintenance. Moistening the thistles with water and cane molasses induced the sheep to consume enough for maintenance, as is shown in trial 39. This, then, is one method of inducing sheep to eat more of the thistles. The silages appeared to be somewhat more palatable than the hays; but, even so, less was consumed than is required for maintenance. Evidently, the thistles should be used as a part of the ration and not as the sole feed.

Russian-thistles usually are laxative in their effect, sometimes excessively so, but in these trials the feces were only soft and pasty. To avoid undue laxative effects, cane molasses was used with the thistles, rather than beet molasses.

No injurious effects from feeding Russian-thistles to sheep have been observed in these trials or in feeding the thistles to bred ewes during four winters.

SUMMARY

Metabolism trials with sheep were conducted in which the composition and digestibility of Russian-thistles (*Salsola kali*) were determined as hay and as silage. The trials included determinations of metabolizable energy and nitrogen, calcium, phosphorus, and magnesium balances.

Six individual metabolism trials on a rather coarse Russian-thistle hay indicated, on a dry basis, 8.5 percent digestible protein, 44.3 percent total digestible nutrients, and 68.44 therms of metabolizable energy per 100 pounds. Five individual trials on a finer thistle hay indicated 10.1 percent digestible protein, 46.7 percent total digestible nutrients, and 67.88 therms of metabolizable energy per 100 pounds.

Three individual trials on ground Russian-thistles with molasses, on a dry basis, indicated 8.2 percent digestible protein, 53.8 percent total digestible nutrients, and 78.03 therms of metabolizable energy per 100 pounds.

Three individual trials on Russian-thistle silage, which included some alfalfa and which had been stored about 2½ years, contained, on a dry basis, 5.3 percent digestible protein, 38.8 percent total digestible nutrients, and 66.08 therms of metabolizable energy per 100 pounds.

Three individual trials on a Russian-thistle-molasses silage, made from chopped fine thistles by adding cane molasses and water, contained, on a dry basis, 9.2 percent digestible protein, 40.5 percent of total digestible nutrients, and 65.46 therms of metabolizable energy

per 100 pounds. This indicates a reduction in the digestible protein, total digestible nutrients, and metabolizable energy as compared to the hay (trial 24).

Three individual trials on silage made from the same lot of hay as the thistle-molasses silage, but preserved with phosphoric acid, contained on a dry basis, 8.3 percent digestible protein, 37.7 percent total digestible nutrients, and 54.26 therms of metabolizable energy per 100 pounds. These values are lower than the values on the same hay preserved with molasses.

The metabolizable energy per pound of digestible organic matter, in all trials, ranged from 1.465 to 1.796, with an average of 1.614 therms.

The metabolizable energy per pound of total digestible nutrients, in all trials, ranged from 1.379 to 1.728, with an average of 1.516 therms.

With one exception, positive calcium balances were observed only in the trials where more than 10 gm. of calcium were fed per 100 pounds live weight.

Positive balances for phosphorus were observed when more than 1 gm. of phosphorus was consumed per 100 pounds live weight, except in two trials.

The data indicate than an abnormally high intake of 4.5 to 5.0 gm. of magnesium daily was required to keep the animal in positive magnesium balance. The low digestibility of the ration may account for these high magnesium intakes.

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RECOVERY AND VIABILITY OF SEEDS OF CERTAIN SOUTHERN GRASSES AND LESPEDEZA PASSED THROUGH THE BOVINE DIGESTIVE TRACT [1]

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INTRODUCTION

The role that domestic animals play in the dissemination of weed seeds has been the subject of study since early in the present century, but many questions are still unanswered. A number of people have expressed the opinion that such southern forage plants as carpet, Bermuda, and Johnson grasses are disseminated by cattle, but a thorough search of the literature has revealed no publications dealing with the recovery and viability of such seeds after passage through the bovine digestive tract. In 1942 and 1945 studies were therefore made to learn what proportion of the seeds of certain southern grasses and lespedeza is digested by Jersey cows and what proportion passes through the digestive tract and still remains viable. The experiments were designed to answer the following questions: Are cattle effective agents in the dissemination of grass seeds? Have they been responsible for the spread of undesirable grasses? How many days are required to clear the bovine digestive tract of viable seeds of the various grasses and lespedeza? What percentage of the seeds of southern grasses and lespedeza consumed are digested and presumably utilized by the cattle for maintenance and growth? The results of the experiments are reported herein.

REVIEW OF LITERATURE

As early as 1907 Hills and Jones (*7*) [3] recognized that commercial feedstuffs contain viable weed seeds that cattle and horses do not digest. Hills, Jones, and Benedict (*8*) continued the studies.

In 1911 Korsmo (*9*) studied this problem by feeding the seeds of six different weeds to horses, cattle, and hogs. He found that seeds which had passed through the digestive tract of cattle germinated better than those of the same species recovered in the feces of horses and hogs.

Beach (*2*) reported that 4.5 percent of weed seeds having a viability of 26.4 percent germinated after passing through the digestive tract of a Jersey cow.

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[3] Italic numbers in parentheses refer to Literature Cited, p. 103.

In India, Milne (*10*) observed that 9.6 to 20.5 percent of the wheat seeds passed by cattle produced plants.

Atkeson, Hulbert, and Warren (*1*) fed dairy cows 1 quart of weed seeds night and morning and recovered the first seeds 47 hours after they were fed. In the 19 samples representing 13 different species studied during the 2 trials, reduction in germination due to digestion was more than 90 percent in 6 samples and 80 percent or more in 11 samples. The writers concluded that the longer the seeds remained in the digestive tract the greater the reduction in germination.

Known quantities of seven weed seeds were fed to calves, horses, sheep, hogs, and chickens by Harmon and Keim (*5*). All of the feces were recovered for 4 days. During this period 23.1 percent of the weed seeds fed to the calves were recovered, and these had an average viability of 45.2 percent. This was the only experiment reviewed in which an effort was made to determine the percentage of seeds recovered.

Dore and Raymond (*3*), using flats in the greenhouse, germinated seeds found in manure droppings from old pastures in southern Quebec. In 6 samples of manure they found 49 species with 167 to 970 seeds per 10 ounces of dry manure. *Agrostis stolonifera* L., *Phleum pratense* L., *Poa pratensis* L., and *Trifolium repens* L. exceeded the other species in the number of viable seeds per unit of manure.

MATERIAL AND METHODS

On October 3, 1942, three mature Jersey cows were placed in separate cement-floored box stalls. From this date throughout the experiment, except as indicated for October 10, these animals were fed a diet known to be free of the seeds of the grasses and the lespedeza (legume) to be studied. An examination of the feces of these cows on October 9 revealed that only a very few seeds of carpet and Bermuda grasses were being passed. Therefore, on October 10, two of the cows were each fed the following seed mixture: Common Bahia grass (*Paspalum notatum* Flügge), 675 gm.; Paraguay Bahia grass (*P. notatum*), 340 gm.; Pensacola Bahia grass (*P. notatum*), 225 gm.; Dallis grass (*P. dilatatum* Poir.), 450 gm.; Johnson grass (*Sorghum halepense* (L.) Pers.), 900 gm.; carpet grass (*Axonopus affinis* Chase), 40 gm.; Bermuda grass (*Cynodon dactylon* (L.) Pers.), 40 gm.; and an unnamed strain of common lespedeza (*Lespedeza striata* (Thunb.) H. and A.) in the hull, 900 gm. The animals consumed an estimated 90 percent of this mixture.

All feces dropped by each animal during each 24-hour period were collected and thoroughly mixed; 200- and 500-gm. samples were taken in duplicate and carefully washed through a series of screens that would retain all the seeds. The material that did not pass through the screens was dried. Seed-cleaning equipment was used to separate the seeds; the number of each species in each 200-gm. sample was counted to permit a calculation of the number of seeds passed during each 24-hour period (table 1). A few seeds of carpet and Bermuda grasses were passed for several days by the third cow, which was fed no seeds on October 10. It was assumed that the cows which were fed seeds passed a similar number of seeds that had been eaten before the experiment was begun and corrections were made in the counts

reported. One of the duplicate 500-gm. samples collected during a 24-hour period was spread out about one-half inch thick on bread pans containing steam-sterilized soil. After all soluble and fine material was washed from the other sample, it was planted in similar pans of sterilized soil. These cultures were watered daily and were kept in a greenhouse heated to temperatures that would favor the germination of the seeds planted. The seedlings of each species in each pan were counted, recorded, and removed at weekly intervals. Such counts for a 12-week period furnished the basis for calculating the number of viable seeds of each species recovered from each cow (table 2).

The caryopses (grains or fruits of grasses) of Dallis, carpet, Bahia, and Bermuda grasses as sold on the market are usually enclosed very tightly in glumes. In such commercial seed lots frequently occur many pairs of glumes that do not contain caryopses because it is difficult to separate them in the cleaning process. These cannot be distinguished from good seeds by outward appearance. In the experiment just described the actual number of caryopses in the seed fed was not determined. The number of seedlings that a known weight of the commercial seed would produce was ascertained by germinating duplicate 100-seed samples in steam-sterilized soil at the same time that the other germination trials were run. From this information it was possible to calculate the number of viable seeds of each species fed (table 2).

In an effort to measure more accurately the influence of passage through the bovine digestive tract on the viability of the seeds of southern grasses and lespedeza, a second experiment was conducted in 1945. Since mature cows were not available, 2-year-old Jersey heifers were used. Three heifers were placed in box stalls with concrete floors and fed a ration free of grass and lespedeza seeds until they were no longer passing seeds of any of the species to be studied. On March 10, 1945, the quantities and numbers of seeds or caryopses shown in table 3 were fed to each heifer. Kobe lespedeza (*Lespedeza striata*) was used instead of common lespedeza in this study. During each 24-hour interval for 10 days, beginning March 11, all feces were collected from each animal. All seeds in each lot of feces were then recovered by the techniques previously described. The number of seeds of each species recovered each day was determined (table 4). Duplicate 100-seed samples of each species were then counted from each lot of seed passed by each heifer during each 24-hour period. In the collections made toward the end of the study there were not enough seeds to give two 100-seed samples. In such cases all of the seeds recovered were counted and used. All 100-seed samples were planted in steam-sterilized soil in the greenhouse and were allowed to germinate for 6 weeks under conditions of optimum temperature and moisture (table 5). Duplicate 100-seed samples of the original seed lots were included in these viability tests as checks. All data from both of these studies were subjected to statistical analyses. The analyses of the 1945 experiment are presented in table 6.

The word "seeds" as used in describing the results of these experiments refers to the true lespedeza seeds and also the caryopses of the grasses, which are usually enclosed in glumes.

RESULTS

The majority of the viable seeds recovered in 1942 were passed during the second day (table 1). It is significant that a few viable seeds of each species were still being passed 10 days after they were fed. However, the quantities of viable seeds recovered on the ninth and tenth days were so small as to suggest that practically all the other viable seeds fed on October 10 had been destroyed by mastication and digestion. Of considerable interest was the observation that the feces of one of the cows, although normal in quantity, contained no seeds alive or dead on the third day. This cow passed many viable seeds on the second and fourth days, however.

The percentage recovery of viable seeds fed to mature Jersey cows was not the same for all species (table 2). Over half of the viable Bermuda grass seeds fed to these cows passed through their digestive tracts and retained their viability. Rather high percentages of living seeds of carpet grass and Pensacola Bahia grass were recovered.

TABLE 1.—*Daily recovery of seeds of several southern grasses and common lespedeza from feces of 2 mature Jersey cows during the 10 days after feeding, October 1942*

Species	Portion of total seeds recovered on day indicated									
	1	2	3[1]	4	5	6	7	8	9	10
	Per-cent	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*
Common Bahia grass	3.3	57.3	6.1	19.2	5.7	2.3	2.6	2.5	0.4	0.1
Paraguay Bahia grass	2.3	51.2	6.2	23.2	8.4	2.9	3.2	1.7	.5	.1
Pensacola Bahia grass	3.2	48.0	10.0	24.4	7.9	2.4	2.1	1.4	.2	.1
Johnson grass	5.4	70.3	8.6	9.5	2.5	.7	2.0	.4	.2	Trace
Dallis grass	4.1	62.0	6.3	20.3	3.3	2.1	1.3	.3	.1	Do.
Carpet grass	5.1	72.9	5.0	12.8	1.6	.8	1.0	.2	.3	.2
Bermuda grass	5.9	60.4	10.0	16.4	3.5	1.7	.9	.7	.1	Trace
Common lespedeza	12.2	72.8	5.1	6.5	1.5	.4	.7	.3	.1	Do.
Average	5.2	61.9	7.2	16.5	4.3	1.7	1.7	.9	.2	.1

[1] Lower than the fourth day because 1 cow passed no seeds.

TABLE 2.—*Viability of seeds of several southern grasses and common lespedeza fed to 2 mature Jersey cows and collected during the 10 days after feeding, October 1942*

[Viability based on total seedlings that appeared in steam-sterilized soil in 12 weeks under optimum temperature and moisture conditions in the greenhouse]

Species	Viable seeds fed [1]	Seedlings from seeds found in feces recovered in 10 days		Viable seeds germinated	
		Washed feces [2]	Unwashed feces	Washed feces [2]	Unwashed feces
	Number	*Number*	*Number*	*Percent*	*Percent*
Common Bahia grass	2,060	42	4	2.0	0.2
Paraguay Bahia grass	10,050	1,520	593	15.1	5.9
Pensacola Bahia grass	35,695	14,851	4,879	41.6	13.7
Johnson grass	82,510	312	1,507	.4	1.8
Dallis grass	81,095	1,055	277	1.3	.3
Carpet grass	48,600	14,200	7,732	29.2	15.9
Bermuda grass	59,985	31,368	21,897	52.3	36.5
Common lespedeza	315,525	1,577	329	.5	.1

[1] Calculated from viability and weight of seed fed.
[2] All material finer than the smallest seeds was washed from the feces.

On the other hand, less than 2 percent of the viable seeds of Dallis grass, Johnson grass, and common lespedeza ingested retained their viability after passing through the cows. It is important to note that some viable seeds of all species were recovered, since some may be seeds of serious weeds. Viable seeds of all species were found in washed feces collected up to 7 days after the seeds were fed to the cows. Viable Bermuda grass seeds were still being passed at the end of 10 days.

In most instances the seeds in washed feces germinated better than those in unwashed, perhaps because of the higher salt concentrations in the unwashed feces. Seeds of Johnson and Bermuda grasses seemed relatively better able to germinate in unwashed feces than those of the other species included in this test.

In the first experiment all records were based on the viability of the seeds fed and recovered. This test failed to show whether the loss in viability was due to the destruction of the seeds by mastication and digestion or was a result of the digestive juices acting upon the seeds without causing external change. It obviously failed to indicate the quantities of seed that were digested. To obtain this information, the actual numbers of seeds and caryopses fed and recovered were determined in a second experiment, conducted in 1945 (table 3). These data show that approximately half of the Bahia and Bermuda grass seeds were recovered, while less than 12 percent of the lespedeza seeds passed intact through the digestive tract.

TABLE 3.—*Seeds of several southern grasses and Kobe lespedeza fed to and recovered from 3 Jersey heifers, March 1945*

Species	Seeds fed (Mar. 10)		Seeds recovered (Mar. 11–20)
	Grams	*Number*	*Number*
Common Bahia grass	330	130,260	61,950
Pensacola Bahia grass	175	176,770	93,460
Johnson grass	440	251,420	82,440
Bermuda grass	40	307,690	145,260
Carpet grass	60	248,570	82,160
Dallis grass	250	208,660	47,470
Kobe lespedeza	150	121,460	14,405

The daily recovery of southern grass and lespedeza seeds passed through the digestive tracts of the three heifers used in this experiment is summarized in table 4 and statistically analyzed in table 6. The analyses show that the cows passed significantly different quantities of seeds, that some species passed through the digestive tract more successfully than others, and that the quantities recovered from day to day differed significantly. The cows × days interaction was highly significant because the seeds did not pass through each cow with the same speed. The highly significant species × days interaction proves that not all the species passed through the digestive tract at the same rate. Table 4 shows that the seeds of the small-seeded grasses like Bermuda and carpet grasses passed through the digestive tract faster than those of the large-seeded species such as Johnson and Bahia grasses.

Since there was a gradual decline in the number of seeds recovered after the fifth day and in most cases less than 1 percent of the seeds

were passed on the tenth day, it is safe to conclude that very few seeds would have been passed later. It is logical to assume that most of the seeds not recovered were digested and contributed to the nutritional needs of the animals. If this assumption is correct, the data in table 4 would indicate that 88 percent of the lespedeza seeds, 77 percent of the Dallis grass seeds, 67 percent of the carpet and Johnson grass seeds, and approximately 50 percent of the Bermuda and Bahia grass seeds were digested. These percentages are inversely proportional to the hardness of the seeds and their protective coverings.

TABLE 4.—*Seeds of several southern grasses and Kobe lespedeza recovered daily in feces of 3 Jersey heifers during the 10 days after feeding, March 1945*

Species	Seeds recovered per 10,000 fed on day No.—										Total
	1	2	3	4	5	6	7	8	9	10	
Common Bahia grass	174	795	1,043	492	993	687	339	129	69	35	4,756
Pensacola Bahia grass	155	897	1,228	607	972	700	465	163	62	38	5,287
Johnson grass	92	639	780	379	558	441	230	112	32	16	3,279
Bermuda grass	190	1,286	1,271	585	583	428	249	71	39	19	4,721
Carpet grass	159	769	916	346	416	395	185	62	40	16	3,304
Dallis grass	62	282	506	327	412	313	189	119	43	22	2,275
Kobe lespedeza	64	284	361	100	166	84	81	21	12	13	1,186

The data in table 5 show the influence of time spent in the digestive tract upon the viability of the seeds that passed through it. The statistical analyses of the original data from which this table was summarized appear in table 6. If these tables are considered together it is evident that passage through the digestive tract did not affect all seeds in the same way. Although the seeds of most of the species lost some of their viability as a result of passing through the digestive tract, Bermuda grass seeds actually germinated better for having been subjected to the digestive processes for a period up to 6 days after the seeds were fed.

In general, the longer the seeds remained in the digestive tract the lower their viability upon recovery. It is evident that some species lost their viability more rapidly than others in the digestive tract. Table 6 shows that this species × days interaction was highly significant. The Johnson grass seeds used in this experiment were old and low in viability. Since Johnson grass seeds in the first experiment germinated after 7 days in the digestive tract, it seems very probable that the viability results obtained from the second test were influenced by the poor quality of the seeds used. It seems logical to suppose that fresh seeds could retain their viability under adverse conditions for a longer period than old ones.

The highly significant cows × species interaction permits some interesting speculation. Bermuda grass seeds recovered from cow 3 during the 10 days of the test averaged 13 percent higher in germination than Bermuda grass seeds from cow 1 or 2. Since these seeds were germinated in the same flat under carefully controlled conditions, the differences could not be credited to the germination technique. Seeds of the other species lost as much of their viability in passing through cow 3 as through the other cows in the test. Evidently the digestive processes of the heifers in this test differed enough to have a differential effect upon the viability of the ingested seeds of certain species.

TABLE 5.—*Viability of seeds of several southern grasses and Kobe lespedeza recovered daily in feces of 3 Jersey heifers during the 10 days after feeding, March 1945*

[Seeds planted in steam-sterilized soil and allowed to germinate for 6 weeks under optimum temperature and moisture conditions in the greenhouse]

Species	Seeds germinating before being fed	Seeds germinating after being recovered on day No.—									
		1	2	3	4	5	6	7	8	9	10
	Per-cent	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*
Common Bahia grass	19	19	15	11	9	6	4	2	1	1	0
Common Bahia grass (scarified)	38	37	29	21	14	11	9	2	1	1	2
Pensacola Bahia grass	73	37	39	35	25	15	12	6	2	5	1
Pensacola Bahia grass (scarified)	77	46	50	43	34	22	16	14	4	3	3
Johnson grass	17	10	4	1	0	0	0	0	0	0	0
Bermuda grass	62	78	85	83	82	79	70	61	51	51	46
Carpet grass	43	68	57	34	28	19	14	3	7	12	1
Dallis grass	34	47	35	12	6	2	0	0	1	0	0
Kobe lespedeza	20	5	7	7	9	12	10	9	7	8	2

TABLE 6.—*Analyses of variance of recovery and viability of seeds of several southern grasses and Kobe lespedeza passed through the digestive tracts of 3 Jersey heifers, March 1945*

Source of variation	Degrees of freedom	Mean square of number of seeds recovered per 10,000 fed	Mean square of percentage of seeds germinating
Cows	2	184,645**	78
Species	6	660,816**	15,709**
Days	9	1,850,892**	2,339**
Cows×species	12	15,333	121**
Cows×days	18	227,963**	67
Species×days	54	71,372**	265**
Error	108	11,698	35

**F exceeds the 1-percent level of significance.

DISCUSSION

The number of days required to clear grass seeds from the digestive tract of a cow is of considerable practical importance. Particularly is this true if the seeds consumed are those of weeds that are difficult to control. Cattle have been charged with the spreading of Johnson and Bermuda grasses. Lawsuits have even been filed against individuals who sold cattle that infested the buyers' fields with Johnson grass seeds.

It is evident from the results of the foregoing experiments that cattle will pass viable seeds of all the species studied for at least a week after they have been removed from the source of the seeds. In order to prevent cattle from carrying seeds of such plants from one field to another, it will be necessary to remove them from the source and give them feed known to be free of the seeds for at least 10 days to 2 weeks.

Carpet grass, an introduced species, is now widely distributed in the flatwoods of Georgia and Florida. Since man rarely seeded it in these sections the dissemination of the seeds cannot be credited directly to him. It is generally believed that cattle have been the principal agents of dissemination. The results of the experiments reported herein indicate that seeds of the forage grasses which will probably be

used in the piney-woods sections for pasture improvement can pass through the digestive tracts of cows and germinate in the feces. How effective cows may be as agents in disseminating the seeds and establishing the new area can only be suggested at this time. The length of time during which the grasses produce viable seeds, the palatability of the seeds and seedstalks, the range of the animals consuming the seeds, the number of defecations of the animals, and the location of salt, water, and shade are all factors that will influence the efficacy of cows in establishing a new grass. Bahia grass, for example, produces viable seeds continuously for approximately 150 days during the year. Dukes (*4*) reported that dairy cows defecate 10 to 24 times daily. During a single seed-producing period one cow might be expected to defecate from 1,500 to 3,000 times, each dropping carrying viable Bahia grass seeds. The presence of the plant food in the feces should help to insure the establishment of the grass in each dropping. In the cut-over piney woods where water and shade are naturally scattered, a good random distribution of the droppings should result from exercising some care in moving salt boxes. Widely separated strips of the Bahia grass established by man at very little cost could serve as a seed source for the cattle. It is conceivable that man may come to recognize the cow as an effective partner in reseeding the cut-over piney woods of the Southeast.

If it is correct to assume that the seeds not recovered in this experiment were digested, it may be concluded that the seeds of the forage plants considered here do, as suggested in the introduction, contribute to the nutrition of the cattle consuming them. These experiments suggest, for example, that 88 percent of the lespedeza seeds consumed were digested. Yields of 500 to 600 pounds of lespedeza seed per acre are not uncommon. Herman and Ragsdale (*6*) compared finely ground Korean lespedeza seed with a mixture of cottonseed and soybean meals as the main source of protein for lactating cows. They concluded that the proteins of ground Korean lespedeza seed were equal pound for pound to the proteins of a mixture of equal parts of cottonseed and soybean meals in the ration of lactating cows. Perhaps this helps to explain why cattle fatten well when grazing lespedeza in the late summer and fall.

SUMMARY

Known quantities of seeds of common, Paraguay, and Pensacola Bahia grasses, Johnson grass, Dallis grass, carpet grass, Bermuda grass, and common or Kobe lespedeza were fed to mature cows and heifers. The seeds of each species recovered at daily intervals and the viability of the seeds recovered were determined in two experiments.

The majority of the seeds fed were recovered in the second and third days, but a few seeds of each species were still being passed 10 days after they were fed.

In most instances the seeds germinated better in washed feces than in unwashed. Johnson grass and Bermuda grass seeds germinated relatively better in unwashed feces than the other species studied.

Statistical analyses of the results revealed that cows that were fed the same quantities of seed passed significantly different amounts, that seeds of some species passed through the digestive tract more successfully than others, that the quantities of seed recovered from day to day differed significantly, and that the seeds of all species did not pass through the digestive tract with the same speed. The seeds of the small-seeded grasses passed through the digestive tract faster than those of the large-seeded grasses.

Approximately one-half of the Bahia and Bermuda grass seeds fed, one-third of the carpet and Johnson grass seeds fed, one-fourth of the Dallis grass seeds fed, and one-eighth of the lespedeza seeds fed were recovered in a 10-day period. The evidence presented indicates that most of the seeds not digested were passed within 10 days after the seeds were fed.

Passage through the digestive tract reduced the viability of the seeds of most species in varying degrees but actually induced a greater number of Bermuda grass seeds to germinate.

In general, the longer the seeds remained in the digestive tract the lower their viability upon recovery. Seeds of some species lost their viability more rapidly than others.

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